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# Recommendations for Knowledge Desk Configurations for U.S. Navy Fleet Command Centers

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## ADMINISTRATIVE INFORMATION


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This report was prepared as part of SSC San Diego's ongoing Knowledge Web Technologies (KWT) project, sponsored by the Office of Naval Research, Future Naval Capabilities Program, with Mr. John G. Kuchinski as Program Officer. Mr. Rey Yturralde, SSC San Diego, is the principal investigator on the KWT project. One goal of this project is the transition of multi-headed displays known as Knowledge Desks for use in advanced military command centers ashore and at sea. This report sets forth some of the issues and recommendations for tailoring Knowledge Desks to the users and settings where they will be provided.

This report is the culmination of a great deal of development, testing, and evaluation over several years. The authors would like to thank the following individuals whose efforts and input served as the basis for our present-day understanding and recommendations:

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# EXCUTIVE SUMMARY

The Navy's desire to move to a "network-centric" concept of operations (Alberts, Gartska, and Stein, 1999) has placed severe demands on the ability of warfighters to process diverse information in a limited period of time. The Office of Naval Research (ONR) Command 21 program and Knowledge Web Technologies (KWT) project within the ONR Knowledge Superiority and Assurance Future Naval Capabilities programs have developed various solutions that take advantage of web-enabling technologies to assist warfighters in being more effective decision-makers in network-centric command and control. One technology that was identified, and for which fleet operators have made numerous requests, is an innovative hardware solution that is a significant capability enabler. These hardware solutions are referred to as "Knowledge Desks" (K-Desks). This report defines the functional requirements for K-Desks, based on current human factors research and operational experience observed as part of the Command-21 and KWT efforts during Operation Enduring Freedom and Operation Iraqi Freedom aboard USS *Carl Vinson* (CVN 79) and USS *Constellation* (CV 64). (See Figure ES-1.)

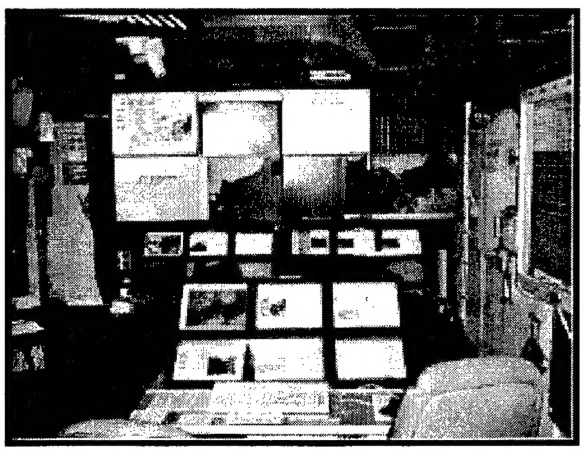

Figure ES-1. KWall and triple K-Desk configuration in Tactical Flag Command Center (TFCC) of USS *Carl Vinson* during Operation Iraqi Freedom.

In short, the available research findings and operational experience suggest that warfighters serving as watchstanders would significantly benefit from workstations with four to six displays integrated as a single desktop (Figure ES-2), while non-watchstanders would benefit from workstations with three to four displays. (See Figures ES-3 and ES-4.) Watchstanders are primarily "information consumers" who must often monitor many sources of information concurrently, including:

- Six to eight text chat rooms (often spread across two displays).
- One or more tactical (geospatial) pictures in dedicated displays.
- One or more status displays, e.g., a web pages.

- Generating e-mail.
- Working on one or more information products on an intermittent basis in one to two displays.

| | | |
|---|---|---|
| **IE (browser)** | **Production Tool(s)** | **Chat** |
| **Product Report(s)** | **Outlook (E-Mail)** | **Chat** |

Figure ES-2. Typical schematic six-display K-Desk configuration.

| | | |
|---|---|---|
| **GeoPlot** (C2PC or GCCS-M) | **Chat & E-Mail** | **Office Tools/ KWeb** |

Figure ES-3. Typical three-display K-Desk for producers.

| | |
|---|---|
| **GeoPlot** (C2PC or GCCS-M) | **Outlook (E-Mail)** |
| **Chat** | **Office Tools/ KWeb** |

Figure ES-4. Typical producers' four-display K-Desk.

For collocated watchstanders, configuring the K-Desks so that some displays might be shared can offer a significant advantage.

We have identified a second group of warfighter decision-makers whose display requirements are somewhat different. These are warfighters are not on watch, but typically still process significant amounts of information, often working as "information producers." These information producers are consuming a variety of information and processing it to create new or derivative "value-added" information that is then shared or distributed to fellow warfighters. The best available information suggests that single desktops with three or four displays can significantly improve the efficiency and effectiveness of these warfighters.

The specific number of displays required for a watchstander in a command center should be based on an analysis of the information processing requirements for each task of watch position, which then serves as the basis for an engineering trade study to identify the optimal watch station display configuration.

Thorough studies of task characteristics that impact the optimum number of displays for a workstation are needed, along with studies to determine the effects of the layout of information (i.e., the number of windows on a display, the number and arrangement of the displays, and the presentation of information in the windows) used by the warfighter. Comprehensive studies are needed to determine the following:

1. Types of tasks that require multi-monitor displays.
2. Effects on cognitive workload.
3. Display configurations that best support cognitive processes (e.g., monitoring, decision-making, data integration, pattern recognition involved in warfighter tasks).
4. Effects of user control over display configuration on task performance.

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# INTRODUCTION

## PURPOSE

This report documents the emerging requirements of warfighters in U.S. Navy Command Centers to display and interact with large amounts of information simultaneously. The requirements are not exclusively for higher resolution displays, but for larger virtual desktops, so that information from a number of sources, in a number of software applications, can be viewed simultaneously. Rather than needing to visualize more detail of documents and graphics, i.e., needing higher resolution in individual displays, the need is to simultaneously view a number of information products concurrently. This report also provides recommendations for alternative workstation configurations based on the best available research.

## BACKGROUND

Today's information display requirements are somewhat different from past requirements. Historically, the technical limitation has been one of resolution, that is, the ability to provide information in the form of pixel density per unit area of the display. Modern computer displays offer very high resolution—1280 x 1024 pixels with thousands of colors is readily available. However, most users rarely use their systems at the maximum resolution, which suggests that usability is no longer a matter of resolution. What is significant, however, is that users often have two to four software applications open on their virtual desktop at the same time, with more applications minimized in the background. Operators must then swap from one application to the next as they perform various tasks.

Today a wide range of knowledge workers in different industries, ranging from stockbrokers to multimedia artists, are adopting multi-display workstations to improve their efficiency and effectiveness. These multi-display workstations provide larger virtual desktops (typically spread across multiple displays) in which to perform the tasks they need to accomplish their jobs. These tasks involve monitoring status information that is dedicated to particular displays, while other displays are used for work space.

Because a single computer drives all the displays as a single large desktop, content can be readily moved by dragging-and-dropping from one software application to another. Such multi-display workstations are supported by commercial off-the-shelf (COTS) hardware and operating systems, including the Microsoft® Windows® workstations deployed as Fleet Information Technology 21st Century (IT-21) and Navy Marine Corps Internet (NMCI) workstations, as well as UNIX®-based workstations. These enlarged workspaces allow the users to be more efficient by facilitating their ability to use information from several files or sources without slow, clumsy, and time-wasting navigation among layered windows in a single display, or worse yet, having to move information among completely separate information technology systems.

These multi-display requirements are just as relevant for users in U.S. Navy command centers as for users in the commercial or business world. For many warfighters, the requirements are even more acute because of the time-critical nature of their tasks and the quantity and scope of information they must monitor and integrate. Watchstanders in operational command centers are consumers who often must monitor numerous status displays in sequence while monitoring and/or participating in ongoing information exchanges, e.g., chats. As the Navy has moved to computer-based collaboration in recent operations, e.g., during Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), chat

tools have become core applications. The need to monitor multiple windows has become more acute and more widespread.

Members of a command staff responsible for planning and assessing ongoing operations often must use three or four different software applications in the course of doing their jobs as producers of information products. As observed during OIF and OEF, a critical aspect of producing near-real-time information involves the warfighter monitoring ongoing chats, sometimes in 6 to 12 text chat rooms at any given time, while actively participating in two to four chats during several hours[1] (Schermerhorn et al., 2003). Watchstanders, who function as consumers, often need to monitor even more information. Watchstanders represent the ultimate consumers in an operational command center because they are responsible for "working the seams" between the plan and actual operations. As a result, they often need to monitor higher numbers of applications and even more chat rooms than the warfighters working outside the operational command center[1] (Moore et al., 2003).

Figure 1. K-Desk.

As the Navy recognizes these issues and attempts to provide better solutions for command center users, guidance is required to ensure that the new solutions will accomplish their intended purpose. This report describes the requirement for multi-display workstations and provides recommendations for hardware solutions based on COTS technologies. These recommendations are based on operational experience at several Joint Wargames (Oonk et al., 2002), as well as empirical studies and survey results from fleet users during OEF and OIF. This report will provide the following:

1. Current knowledge about command center requirements with respect to staff workstations, which we call Knowledge Desks (K-Desks).

2. Information about potential solutions to meet command center requirements, with selection criteria and lessons learned, given current technology and market information.

[1] B. Feher, J. G. Morrison, and N. Heacox. 2003. "Chart Usage in the Fleet: Warfighter Survey Results." SPAWAR Systems Center, San Diego, CA.

## Technological Advances

A well-established pattern of technological advancement has occurred in the information technology industry—rapid product improvement with declining costs. Thus, initially costly display technology has become more compact and energy-efficient, providing higher resolutions, and shifting from cathode ray tube (CRT) technology to liquid crystal display (LCD) technology, all while becoming more affordable. Advancements in display technology have been accompanied by faster, more powerful, higher resolution video processing technology, leading to affordable video display cards that can drive multiple displays.

At the same time, operating systems have taken advantage of these technological capabilities by offering a means to easily distribute the workspace across multiple displays. These combined technological and economic advances can provide new workstation capabilities for knowledge workers. Many have adopted these capabilities, although their advantages are often based more on anecdotal evidence than on scientific evaluation.

## Benefits and Costs

Intuitively, there are many advantages to having multiple monitors when working on more than one task or document. First, they are a relatively inexpensive and flexible means to provide additional display real estate to a computer desktop. From a human factors perspective, multiple computer monitors reduce the need for interaction with the mouse and keyboard because they allow users to scan multiple information sources using only eye and head movements relative to a single monitor. They also reduce the need to "minimize" windows (e.g., view one workspace or application while keeping others running "in the background"), which decreases users' reliance on working memory needed when switching between and/or integrating information across workspaces (Baddeley, 1986; St. John et al., 1999). The ability to view more than one workspace at a time may also prevent users from missing important changes or alerts that would otherwise occur in the "hidden" workspaces. Upon initial consideration, therefore, it seems that the more monitors, the better. However, a human factors perspective suggests that there are probably going to be performance tradeoffs associated with increasing the number of available monitors.

Presenting multiple information sources simultaneously to users does not necessarily make it easier to integrate that information (e.g., Oonk et al., 2000). Too much information presented simultaneously may increase cognitive load (Sweller, 1988) associated with a cluttered visual environment. Increasing the amount of available screen space puts some information in the user's visual periphery, increasing the number and size of required eye, head, and mouse movements (Fitts, 1954; Gillan et al., 1990; Robinson, 1979; Whisenand and Emurian, 1999). In its "widest" configuration (i.e., at least three monitors are active[2]), information at the centers of the peripheral monitors of the K-Desk can be separated by 52° (60° separates information on the two farthest ends of the K-Desk). Previous research has suggested that looking at a target a small distance away from center (20° to 30°) usually involves a single, discrete eye movement. However, viewing information that is more than 30° in the periphery requires additional eye and, sometimes, head movements (Robinson, 1979), each of which contributes additional motor programming and movement time. Mouse movement times increase as the distance to the target increases, even for very short (4° or more) distances (Whisenand and Emurian, 1999). Placing information further away from the visual

[2] See the Method sections for each experiment for a description of the different monitor configurations examined in the two experiments.

center also increases the detection times for even very salient visual events (Thackray and Touchstone, 1991), which suggests that users of multiple monitors may detect more slowly, or miss entirely, important alerts or changes that occur in peripheral monitors.

### Military Studies

St. John, Harris, and Osga (1997) compared response times in a multi-tasking environment for multiple, overlapping windows in single displays to multiple monitors that allowed the same windows to be spread out over a larger workspace. They "found that accessing information distributed across an array of monitors was at least as effective as locating and managing windows on a single monitor." They also found that "a task that requires only infrequent monitoring can be moved to a secondary, peripheral monitor without disrupting performance on that or any other concurrent task."

St. John, Manes, Oonk, and Ko (1999) examined several alternatives for using multiple workspaces to improve multi-tasking in U.S. Navy command and control environments. Multiple workspaces provide large virtual desktops to facilitate user access to task-related information. Two experiments were conducted that compared performance with multiple displays to performance with rapid switching between an equivalent number of workspaces. In both cases of two displays and cases of four displays, they found nearly equivalent performance using an optimized switching paradigm based on a workspace control diagram compared to performance when working with multiple displays.

# DEFINING OPTIMAL SOLUTIONS FOR NAVY REQUIREMENTS

## SSC SAN DIEGO LIMITED OBJECTIVE EXPERIMENT (LOE)[3]

The Limited Objective Experiment (LOE) consisted of two LOEs to determine optimal solutions for U.S. Navy command centers. These experiments addressed the question of how the number of displays on the workstations of military staff members affects the performance of typical tasks. A survey of users in the Fleet was used to identify principle tasks and workload of warfighters in operational command centers according to staff role: information producer or information consumer.

In the producer experiment, participants were required to create an integrated "knowledge product" using information from many disparate sources, similar to planners and analysis staffs. In the consumer experiment, participants were required to monitor the status of an operational mission and maintain situation awareness as would be expected of a watchstander in an operational command center. In both experiments, participants were required to concurrently perform other tasks—communicating in chat sessions, responding to e-mails, and monitoring a tactical display. Performance on the various tasks was assessed in terms of speed and accuracy as well as situation awareness in various display conditions: one, two, three, four, and six monitors. These measures were analyzed separately and in total.

As expected, the pattern of results (summarized in Figure 2) depended on the tasks that the participants performed in the experiments. Overall, the four-monitor condition supported the best performance in the producer and consumer experiments. For consumers, performance improved as the number of monitors increased, up to a point of diminishing returns after four monitors. Contrary to predictions, producers were not found to require fewer monitors to perform their tasks than consumers who performed information integration tasks. The optimum condition in terms of user preference was also the one in which participants performed the best—although this is not always the case in applied experiments (Andre and Wickens, 1995; Bailey, 1993).

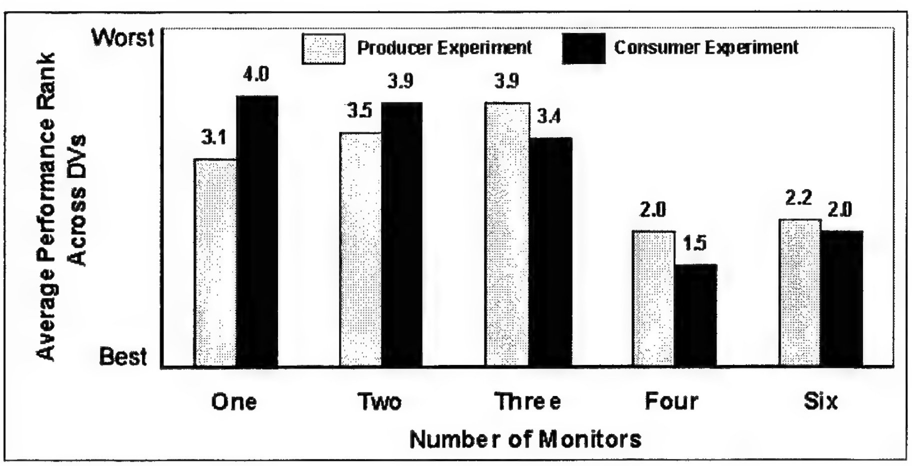


Figure 2. Average ranks derived when comparing performance across all dependent variables measured in the producer and consumer experiments.

[3] Based on Oonk et al., 2003

Based on the findings of the two LOE experiments summarized in this paper:

- Four monitors are recommended for producer tasks involving creation of information products through the integration of multiple sources of information, concurrent with monitoring of incoming information and responding to requests for information. Figures 3 and 4 show sample three-display and four-display layouts.

| | | |
|---|---|---|
| **GeoPlot (C2PC or GCCS-M)** | **Chat & E-Mail** | **Office Tools/ KWeb** |

Figure 3. Typical three-display K-Desk for producers.

| | |
|---|---|
| **GeoPlot (C2PC or GCCS-M)** | **Outlook (E-Mail)** |
| **Chat** | **Office Tools/ KWeb** |

Figure 4. Typical producers' four-display K-Desk.

- At least four, and up to six or more monitors are recommended for consumer tasks involving monitoring of an operational situation concurrent with monitoring of incoming information and responding to requests for information. Figure 5 shows an exemplary layout.

| | | |
|---|---|---|
| **IE (browser)** | **Production Tool(s)** | **Chat** |
| **Product Report(s)** | **Outlook (E-Mail)** | **Chat** |

Figure 5. Typical schematic six-display K-Desk configuration.

- Research is needed to compare performance in these tasks in a more robust manner, preferably including instrumentation to allow a more detailed analysis in how to optimally configure and present information within the multi-monitor workstations.

Conclusions based on the pattern of results in Figure 5 assume that each of the performance measures should be weighted equally. However, the results suggest that the optimum number of monitors is task-dependent—different for the overall producer and consumer task sets, and also for each of their component subtasks. For example, in the consumer task, if monitoring the operational mission is emphasized, six monitors support superior performance. This observation is an important distinction that should be considered in command center workstations.

# REQUIREMENTS-BASED RECOMMENDATIONS

## BASED ON USER TASKS DURING PRODUCTION AND CONSUMPTION

Warfighters must have enough monitors to support their tasks, but not so many that they are overloaded by information. Overestimation of monitors needed by fleet users can lead to performance decrements and unnecessary fiscal costs. Underestimation, on the other hand, may also result in undesirable performance costs in terms of speed and quality of decision-making. Ideally, research in this direction should allow us to make value estimates per monitor, i.e., best return on investment with respect to performance. Based on the findings of the two LOE experiments summarized in this paper:

- Four monitors are recommended for producer tasks involving creation of information products through the integration of multiple sources of information, concurrent with monitoring of incoming information and responding to requests for information.
- At least four, and up to six or more monitors are recommended for consumer tasks involving monitoring of an operational situation concurrent with monitoring of incoming information and responding to requests for information.
- Research is needed to compare performance in these tasks in a more robust manner, preferably including instrumentation to allow a more detailed analysis in how to optimally configure and present information within the multi-monitor workstations.

### Hardware Components of Knowledge Desks[4]

In late 2002 and early 2003, the SPAWAR Systems Center. San Diego (SSC San Diego) K-Desk consisted of an IT-21-compliant workstation, such as the mini-tower Dell™ Precision® 340 Workstation" computer, and six Sony® SDM-N50R 15-inch LCD flat-panel displays. The K-Desk computer had two Appian Jeronimo™ Pro four-port video cards. The Jeronimo™ Pro video card was an advanced graphics accelerator that used a single high-speed Peripheral Component Interconnect (PCI) bus slot with four video output channels to support up to four video displays. The hardware configuration for this K-Desk configuration was as follows:

- Dell™ Precision 340® Workstation
- Pentium® IV processor 2.2 GHz
- 400 MHz Front Side Bus
- 512 MB RAMBUS RAM
- 20 GB hard disk drive
- Integrated sound card
- Integrated Network Interface Card (NIC)
- Integrated Universal Serial Bus (USB)
- CD ROM
- 250 MB Zip drive

[4] This section is based on a Sonalysts, Inc. deliverable prepared by Stephen Francis for SSC San Diego, entitled "Web Technology Report: Knowledge Desk Assembly and Troubleshooting Guide," dated 18 December 2002.

- 3.5-inch floppy disk drive
- Appian Jeronimo™ Pro four-port video card 32 MB SGRAM (two per K-Desk) with Hydravision™ software.
- Sony® SDM-N50R 15-inch multi-scan LCD flat-panel displays (six per K-Desk)
- K-Desk LCD flat-panel mounting structure

## SELECTION CRITERIA FOR K-DESK COMPONENTS

Many options, price ranges, and trade-offs are available when it comes to constructing multi-monitor solutions. The right solution for a particular situation will depend on user and task requirements and constraints—a universal "best" recommendation is not realistic. Specific needs and potential future expansion may dictate the most desirable choice.

At the low end of the spectrum, a solution is simply placing multiple monitors/LCDs next to each other and driving them with multiple video cards (many COTS video cards will work fine). Using a special multi-monitor video card may be required to provide support for a large number of displays if PCI slots are limited. As an example, a tri-panel LCD display system would cost under $1000 for a multi-monitor graphics card and three good quality LCDs. Using three COTS video boards and standard video monitors (instead of LCDs) could reduce costs further.

With regard to video cards for multi-head systems: video cards may be added to Windows® 2000/XP computers to drive the desired number of monitors, but this solution will only work until the computer's PCI slots are used up. This solution also introduces the danger that some video cards may not play nicely together. Therefore, a better solution is to use a special multi-monitor video card. We have used various multi-monitor video cards over the years—each has advantages and disadvantages. Manufacturers of competitive products include ColorGraphics (www.colorgraphic.net), Matrox® Graphics Inc. (www.matrox.com), and Appian Graphics® (www.appian.com). Most multi-monitor video cards cost several hundred dollars, but they come with special software that makes monitor management vastly easier, and they eliminate the headaches of finding multiple, separate video cards that are compatible in the same computer.

For multiple monitors, the next step up is a commercially packaged integrated monitor solution (which still requires one or more multi-monitor video card(s) to drive them). We use MASS™ Multiple displays in our lab and we have been pretty happy with them, but any solution has pros and cons. You can find information on them at Mass Multiple (www.massedi.com). They offer several attractive, very cost-effective solutions. As an example, the cost per unit for a triple 15-inch LCD display is about $1500, and a triple 18-inch LCD display costs about $3000. The Appian Graphics® card we use (the Rushmore™) has dropped to about $530.

Farther up the cost-ladder are higher end, special-purpose, and/or ruggedized solutions. For example, the Navy's Commander-in-Chief 21st Century (CINC 21) project currently uses multiple displays from Panoram Technologies (www.panoramtech. com). These displays are relatively expensive in comparison to the solutions above.

In summary, using COTS hardware with existing central processing units (CPUs) and display systems is a cost-effective means for economically assembling a K-Desk system.

Appian Graphics® (www.appian.com) is no longer producing the Jeronimo™ Pro cards that were used to drive the multiple video outputs for the K-Desks. However, Appian's Rushmore™ is currently their top production video card for multi-monitor support. In addition to the functionality

that the Jeronimo™ Pro cards provided, the Rushmore™ provides increased onboard video RAM, a smaller PCI form factor, and a later version of the Hydravision™ software with added features. The Rushmore™ video cards are already used in current K-Desks, and they were easily installed via plug-n-play. They did not produce any technical difficulties that required manual configuration changes with multiple cards, unlike multiple Jeronimo™ Pros.

Appian's minimum system requirements for a single installed Appian Rushmore™ video card are 256 MB of RAM and a Pentium® 2 processor. However, when installing two Appian Rushmore™ cards, we recommend at least 384 MB of RAM with a Pentium® 3 (750 MHz or greater). When running multiple applications, especially those with high-resolution graphics or streaming video, system resources are easily used up and can cause slower performance or system crashes. We are currently using Pentium® 4 computers with 512 MB of RAM and two Appian Rushmore™ cards for K-Desks.

Multi-monitor video cards are available from a number of vendors besides Appian Graphics®, but Appian Graphics® has provided superior technical support and customer service compared to that of other vendors that we have tried. For that reason, we still use them as our provider of multi-monitor video cards.

Multi-monitor desktop solutions require some kind of monitor frame or stand. MASS Multiple (www.massedi.com) provides a quick and convenient method of building multi-monitor desktop solutions through fabricated monitor stands with easily installed LCD panels. MASS Engineering Design Inc. offers a number of desktop configurations, including a 2 x 1, 1 x 3, and 2 x 2. They can custom fabricate a 2- x 3- display mount upon request.

Table 1 summarizes typical costs as of December 2002 for the hardware components of a K-Desk, which may be used with a Knowledge Wall that facilitates group information consumption by means of three large screen displays. (One operational installation is shown in Figure 6.) The K-Desks are useful as individual workstations that can occasionally support a small group of individuals who can be in close proximity. Costs for multiple K-Desks can be extrapolated by multiplying the cost of a single workstation times the quantity desired.

| Table 1. K-Wall and K-Desk components and costs. | | | |
|---|---|---|---|
| Table 1a. K-Wall (1 x 3 LSD Stand-Alone) | | | |
| Item | Quantity | Unit Cost | Total |
| Smart Boards and Projectors | 3 | $14,000.00 | $42,000.00 |
| Computer and OS (Windows 2000*) | 1 | $2,000.00 | $2,000.00 |
| Video Cards | 2 | $610.00 | $1,220.00 |
| Smart Board Video Cables | 3 | $70.00 | $210.00 |
| Microsoft® Office | 1 | $600.00 | $600.00 |
| Total Per Unit | | | **$46,030.00** |

*Certified for Secret Internet Protocol Router Network (SIPRNET) use.

| Table 1b. K-Desk (2 x 3 Display Array—Stand Alone) | | | |
|---|---|---|---|
| Item | Quantity | Unit Cost | Total |
| Computer and OS | 1 | $2,000.00 | $2,000.00 |
| Video Cards | 3 | $610.00 | $1,830.00 |
| Display Mount and Assembly** | 1 | $4,200.00 | $4,200.00 |
| Displays | 6 | $800.00 | $4,800.00 |
| Display Video Cables | 6 | $15.00 | $90.00 |
| Microsoft® Office | 1 | $600.00 | $600.00 |
| Total Per Unit | | | **$13,520.00** |

** Display mount less costly in quantity

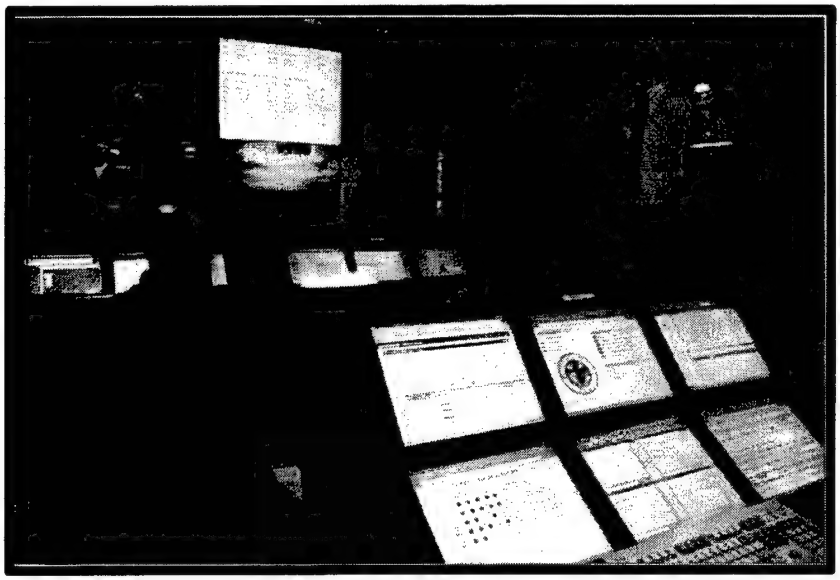

Figure 6. KWall and triple K-Desk configuration in TFCC of USS *Carl Vinson* during OIF.

# DISCUSSION

## LIMITATIONS OF CURRENT WORK

Although there are patterns in the data from the above experiments point to an "optimum" number of monitors for the tasks examined, they also suggest the need for further research. The nature of an LOE, which by definition is a "small-scale" study, restricted the number of participants that could participate in the experiment (and, thus, statistical power) and the length of time for each experimental session.[5] More refined comparisons should be made before the results of the above experiments are adopted as a general workstation specification. Future studies should compare performance in producer and consumer tasks across fewer conditions, using more realistic and sensitive tasks by giving the participants more information to monitor/integrate and longer blocks of time to perform their tasks. Producer studies should focus by comparing three, four, and perhaps, more monitors, while consumer studies should focus on performance with four to six or more monitors.

## RECOMMENDATIONS FOR FUTURE WORK

It is clear that the nature of the decision-making tasks and specific combinations of tasks will have an impact on the optimum number of displays for a given workstation. Further research is needed to compare performance in these tasks in a more rigorous manner. These results can be a first step that will define the parameters under which more interesting issues related to multi-monitor workstations for the warfighter can be explored. In particular, the layout of information that the warfighter uses should be examined to determine, among other things:

1. Types of tasks that require multi-monitor displays.
2. Effects on cognitive workload.
3. Display configurations that best support cognitive processes (e.g., monitoring, decision-making, data integration, pattern recognition) involved in warfighter tasks.
4. Effects of user control over display configuration on task performance.

[5] Data collection took place over a single 4-day period (16–19 September 2002).

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**14. ABSTRACT**

This report defines the functional requirements for K-Desks, based on current human factors research and operational experience observed as part of the Command-21 and KWT efforts during Operation Enduring Freedom and Operation Iraqi Freedom aboard USS *Carl Vinson* (CVN 79) and USS *Constellation* (CV 64).

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